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EXPERIMENTAL DEMONSTRATION OF THE EXISTENCE  
OF A HYDROGEN ION FLUX IN THE EXOSPHERE

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EXPERIMENTAL DEMONSTRATION OF THE EXISTENCE  
OF A HYDROGEN ION FLUX IN THE EXOSPHERE

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ABSTRACT. Detection of a hydrogen ion flux along the magnetic force lines of the earth. It is found that in the middle latitudes of the Northern Hemisphere, this flux is directed toward the earth during the period from four to eight o'clock AM of the local solar time. The energy of the hydrogen ions is found to be below 4 eV. The absolute magnitude of the ion flux is also determined.  
A70-24321

MKh-6405 mass spectrometers were installed on the Elektron-2 <sup>/151</sup> and Elektron-4 satellites [1]. The characteristics and operational parameters of both instruments were almost identical. They were described in [2]. A number of measurements were made by Elektron-4 during July-August, 1964, a period of minimum solar activity. The solar radiation flux with a wavelength of 10.7 cm was  $S = 70 \cdot 10^{26} \text{ w/m}^2 \cdot \text{Hz}$ ; the geomagnetic index  $A_p$  was less than 24. This particular satellite had no specific orientation and it rotated with a velocity of approximately  $2^\circ \text{ sec}^{-1}$ , as a result of which the  $H^+$  ion flux was found to be modulated by the change in the angle  $\theta$  between the satellite velocity vector and the axis of the instrument (angle of attack) (see Figure 1). The arrows indicate additional flux maxima which cannot be explained on the basis of the above-mentioned change in the angle of attack (Curve b, Figure 1). It was found that the amplitude of these additional flux maxima depends significantly on the McIlvain parameter,  $L$ , (see Figure 2a). There is no doubt that this relationship is the manifestation of a significant effect of the magnetic field on this phenomenon. Favorable conditions for recording additional maxima are realized when the angle  $\xi$  between the magnetic field

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\* Numbers in margin indicate pagination in foreign text.

vector and the axis of the instrument is approximately  $70-80^\circ$  (see Figure 1, Curve c), and thus, the main maximum and this additional one do not coincide with respect to time. In this case, the additional maximum flux is approximately  $10^{-12}$  A, while the principal maximum flux is approximately  $10^{-11}$  A, and this additional maximum can be distinguished with respect to the principal maximum. A total of thirty-three additional maxima were recorded. The local solar time of the satellite at the time the measurements were made was between one and eight o'clock.

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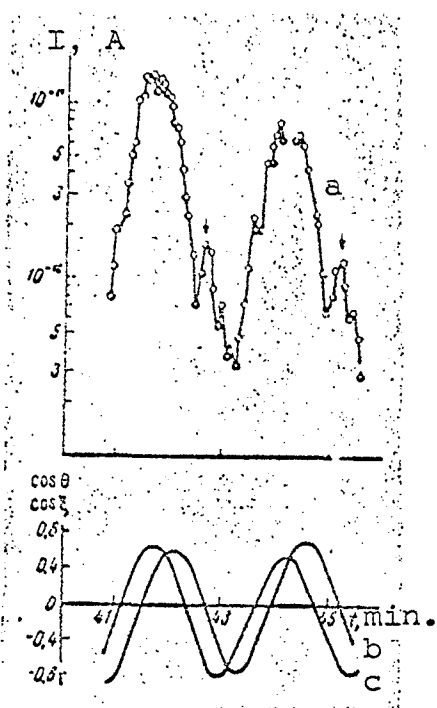


Figure 1. Relationship of  $H^+$  flux to time which shows the changes in the angle of attack  $\theta$  (Curve a) and the relation of  $\cos \theta$  (Curve b) and  $\cos \xi$  (Curve c).

Maximum current must correspond to minimum angle of attack. When  $\xi \sim 70-80^\circ$ , additional maxima are observed.

Fig. 3a shows the typical distribution of the additional flux density as a function of the pitch angle. This distribution includes the aperture function of the instrument so that the distribution of the hydrogen ions along the pitch angle is no wider than a given value. The histogram in Figure 3b gives the distribution of cases of coincidence of additional maxima at ten-degree intervals over the pitch angle. Only in three cases did the additional maxima occur at an angle greater than ninety degrees, which can apparently be explained quite easily by the inaccuracy in the orientation ( $5-10^\circ$ ). The histogram shows only the additional recorded maxima in the four to eight o'clock interval of the local solar time. The fact that the distribution is shifted toward  $70-80^\circ$  angles leads to the conclusion that there

is a proton flux in the morning at the intermediate latitudes of the Northern Hemisphere which moves along the terrestrial magnetic lines of force in the direction of the Earth.

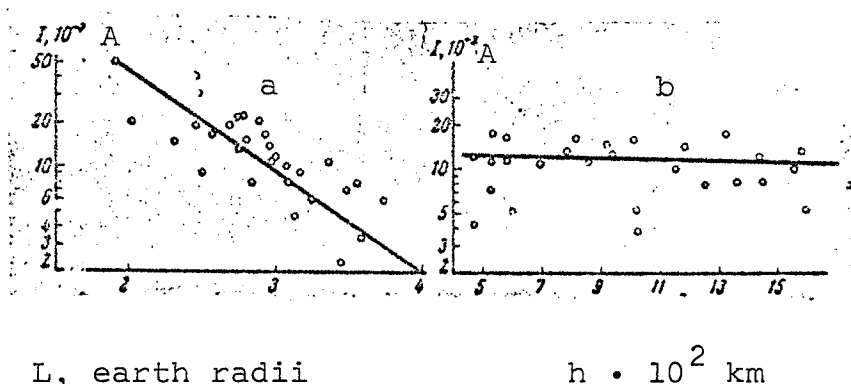


Figure 2. The amplitudes of the additional maxima as a function of the McIlvain parameter,  $L$  (a) and the altitude (data reduced to  $L = 3$ ) (b).

It should be noted that the experimental results which indicate the existence of significant quantities of ions with "superthermal" energies were also obtained on various, previous occasions. Thus, using mass spectrometer analysis, the high-altitude, automatic, geophysical recording station, directed along the vertical axis, detected  $O^+$ ,  $NO^+$  and  $O_2^+$  ions on 18 October 1962 and showed the possible existence of a certain amount of atmospheric oxygen  $O^+$  ions which have superthermal energies and which move either randomly or in a directed flux [3]. Analogous conclusions regarding the possibility of the existence of ion fluxes in the upper atmosphere with velocities of the order of several km/sec were recently made by the American researchers [4] who analyzed the results obtained from sonde measurements conducted early in 1962 by artificial earth satellites directed along the velocity vector. Since it was possible to ascribe different interpretations to the recorded characteristics which are not associated with the ion fluxes, the results of these

measurements cannot be considered congruent.

The estimation of the energy per ion is analogous to that in [5] and it is based on the energy relationship of the experimental number of ions recorded by the mass spectrometer. From the theory of mass spectrometers it is known that the shift in the mass peak on the mass scale  $\Delta M = E/K$ , where  $E$  is the kinetic energy of the ion in eV and  $K$  is a constant peculiar to the instrument and which in this case is equal to 162 v/amu.

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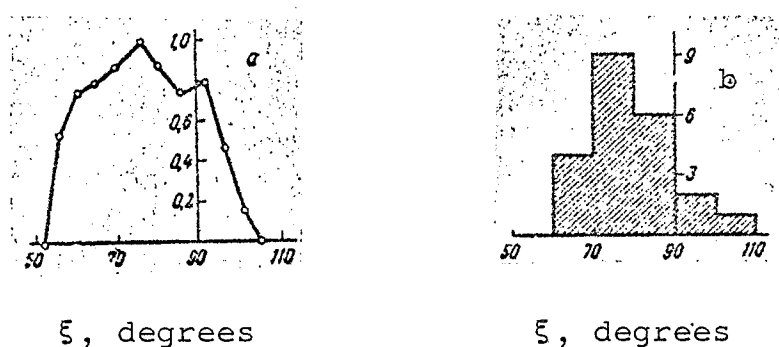


Figure 3. Typical changes in  $H^+$  ion flux (in relative units) in the additional maximum as a function of the pitch angle (flux maximum occurs at angles of  $77^\circ$ ) (a) and a histogram of the pitch angle distribution, drawn for twenty-two cases of the recorded additional maxima: in nine cases the distribution maximum occurred in the  $70-80^\circ$  interval, and in six cases in the  $80-90^\circ$  interval etc. (b).

In the case in question, the accuracy of the method is such that it is only possible to reliably indicate the upper limit of the energy of the ion:  $E < 4$  eV (standard deviation  $\sigma = 1.5$  eV).

Taking into account the relationship to  $L$ , a graph was plotted for the change in the magnitude of the flux with respect to altitude (Figure 2b). It is interesting to note the constancy of the flux up to an altitude of approximately 1,800 km.

The evaluation of the absolute magnitude of the flux is directly dependent on the calibration of the mass spectrometer, which is determined as follows: a certain value was selected for the concentration of  $H^+$  at a given time as for a given observation point. The reaction of the instrument for this concentration was known (ion current). The ion current efficiency was determined as the ratio of the current across the output of the instrument to the true ion current (ion flux) across the input. For a concentration of  $H^+$ , the value  $1.5 \cdot 10^4 \text{ cm}^{-3}$  was selected (according to [6]). Assuming that the  $H^+$  concentration is equal to the electron concentration at an altitude of 1,000 km, the data obtained by the Allouette satellite [7] can also be used in the evaluation. This data gives a value which is in agreement with ours. In addition, the ion current efficiencies for the instruments used in Elektron-2 and Elektron-4, which should agree in view of the identical structure of the instruments, were found to be equal. The first coefficient was obtained from direct measurements of the electron concentration by Elektron-2 [8], while the second was based on the accepted value for the  $H^+$  concentration. As a precautionary measure, if it is assumed that the error in the evaluation of the absolute magnitude is twice the probable error, we arrive at the following values for the magnitude of the flux  $\varphi = 10^8 \text{ ions/cm}^2 \cdot \text{sec}$  when  $L = 4$ , and  $\varphi = 2.5 \cdot 10^9 \text{ ions/cm}^2 \cdot \text{sec}$  when  $L = 2$ , with a probable error of 2-3. The flux along the magnetic lines of force is obtained by multiplying this value by  $\cos \xi = 0.25$  ( $\xi = 75^\circ$ ).

### Conclusions

1. A hydrogen ion flux along the terrestrial magnetic lines of force was discovered.
2. The direction of the flux in the intermediate latitudes

of the Northern Hemisphere at four to eight o'clock, local solar time is toward the Earth.

3. The energy of  $H^+$  ions is less than 4 eV.

4. The absolute magnitude which was determined for the flux is  $\varphi = 2.5 \cdot 10^7$  ions/cm<sup>2</sup> . sec when  $L = 4$ .

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